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PROPOSAL FOR THE DEVELOPMENT OF A COMPUTERIZED GUIDANCE SYSTEM FOR THE EASI-MINER CONTINUOUS MINING MACHINE

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PROPOSAL FOR THE DEVELOPMENT OF A COMPUTERIZED GUIDANCE SYSTEM FOR THE "EASI-MINER" CONTINUOUS MINING MACHINE

by

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ABSTRACT

In this paper, a proposal for the development of a computerized guidance system for the "Easi-Miner" continuous mining machine is presented. A discussion of system accuracy is presented which identifies factors influencing the ability of achieving the desired accuracy. In turn, each of these influencing factors are discussed and, through this discussion, the creation and use of the guidance system is described.

The guidance system is seen as a means of improving the efficiency of the "Easi-Miner" operation, specifically, reducing the present dependence on human judgement for detecting material changes to selectively separate coal from partings and interburden and improving coal recovery.

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PROPOSITION DE MISE AU POINT D'UN SYSTEMEDE GUIDAGE INFORMATISE POUR LA HAVEUSE EN CONTINU "EASI-MINER"

par

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RESUME

Dans la présente communication, on présente une proposition pour mettre au point un système de guidage informatisé pour la haveuse en continu "Easi-Miner". La précision du système est abordée, et on identifie des facteurs qui influent sur la capacité d'obtenir la précision voulue. Chacun de ces facteurs sont ensuite analysés et, dans cette analyse, la création et l'utilisation du système de guidage sont décrites.

Le système de guidage est vu comme un moyen d'améliorer le rendement de la "Easi-Miner", notamment en réduisant la dépendance actuelle à l'égard du jugement humain pour détecter les changements de matériaux dans la séparation sélective du charbon des plans de séparation des morts-terrains et améliorer la récupération de charbon.

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INTRODUCTION

The "Easi-Miner", continuous mining machine, has the capability to excavate, crush, and raise material to a height suitable for loading into haul units or a conveying system. The miner has the ability to excavate relatively thin seams, thereby reducing contamination from partings and interburden. The ability to distinguish between coal and waste is presently dependent on the operators visual inspection to detect different materials and through detection of significant changes in physical vibration of the miner while in operation (1). Both of these methods have definite problems. Because of the dust created during the miner's operation, visual inspection of the material being excavated becomes very difficult. Further, in areas where material hardness remains basically unchanged, physical vibration will remain basically constant and thus this control method becomes unreliable also. Consequently a method is needed which reduces or eliminates reliance on human judgment and improves the operators ability to distinguish between coal and waste.

In this paper, a computerized guidance system is proposed, which, if implemented, would assist in developing more efficient operation of the "Easi-Miner" continuous mining machine. A discussion of system accuracy, introduces limitations imposed on the system which assist in defining an attainable accuracy. Further, the factors influencing the ability of achieving the desired accuracy are presented and, through this discussion, the creation and use of the guidance system is described.

EASI-MINER OPERATION

The "Easi-Miner" was selected for the Bienfait Mine operation for its ability to effectively cut and control the coal horizon, particularly if any irregularity exists in the seam. An established standard practice is to use the first cut as a guide. The operator may observe the previous cut when cutting the second or any following cuts and visually judge how well he

negotiated the floor. If hard lenses of vaste material are encountered (sandstones, etc.), the machine comes under stress and there is a noticeable vibration throughout the machine. The operator is then forced to slow the machine down and raise the cutting head. During this adjustment he may loose the prescribed level of the machine and increase ash content of the coal by removing some vaste material during coaling operation. The visual adjustment of the machine level depends on the operator, his experience and ability to recognize various material in the coal sequence.

The Bienfait Mine is purchasing Huron's "Easi-Miner" because it was felt that this type of machine best suits the mine requirements. The "Easi-Miner's" cutting head rotates in the direction of machine travel, eliminating possible problems in material handling.

SYSTEM ACCURACY

When assessing system accuracy one must investigate the limitations imposed on the system, including geological, mechanical, and human limitations. Using the present system (operator visual inspection and vibration change detection), it is accepted that the "Easi-Miner" excavating accuracy is approximately (+/-) 10 cm (2). However, the non-uniform line separating coal from waste can be defined within a range of (+/-) 1 cm. Evidently the present system is often inadequate and will result in excessive contamination of coal when encountering underlying waste, and lost coal when removing waste from underlying coal seams. Further this system does not permit economical removal of some thin coal seams. The human and mechanical limitations of the present system result in a mining accuracy far outside the range of the geological limitations defined by the coal/waste separation lines. To fully utilize the "Easi-Miner", a system accuracy should be defined which meets or exceeds the geological limitations of these coal/waste separation lines.

For the proposed system discussed in this paper, (ie. Computerized Guidance System), numerous factors will affect the ability of achieving such an accuracy.

1. Method of Data Base Acquisition
2. Data Base Interpretation/Management
3. Update or Adjustment System

Each of these factors are outlined in the following discussion.

METHOD OF DATA BASE ACQUISITION

The proposed guidance system can be used only in relatively flat laying coal seams, where uniform thickness of coal and partings is apparent. The system will operate through interpretation of a computer data base containing coordinates of the upper and lower boundaries of minable coal and waste zones. In essence, these coordinates will represent a "digital terrain model (DTM)" of each coal seam boundary. Through knowledge of the position (x,y,z) of the "Easi-Miner" cutting head within the DTM, a corresponding cutting depth can be established such that contamination of the mined material from underlying material is minimized. The accuracy of this "cutting depth" is dependent on, amongst other factors, the accuracy of the coordinate data base.

In order to determine the coordinates of the coal and waste boundaries, a mine site surveying method must be used. In this paper, two surveying methods will be presented. First, the method of terrestrial photogrammetry is discussed, then a method using conventional survey equipment and techniques.

Terrestrial Photogrammetric Method

Terrestrial photogrammetry, involves taking photographs of the exposed seams and, through formation of stereomodels of the images, determine coordinates of the coal and waste boundaries. These "stereomodels" enable points on the boundaries to be digitized very easily and form the basis of the coordinate data base. The photographs would be taken from the spoil side of the pit facing the exposed geology. An accuracy of (+/-) 1 cm could easily be obtained for boundary points, provided the relative accuracy of the exposure stations and control points is determined to at least this accuracy and better. The entire procedure including photography, digitizing, and data base formulation is estimated to require no more than 5 days. However, the initial preparation of exposure stations and control points, and familiarization with the working area and procedures, would make the first "run" of longer duration. Obviously the procedure will require less time with each subsequent "run". This procedure would be repeated at least every two months depending on the block size, changes in seam topography, and production rate. The cost of a photogrammetric survey and the time required to process the observations are significant disadvantages in this method.

From the results of the photogrammetry, in addition to obtaining the desired coordinate data base, in-site volumes of coal and waste within a block for example, could be much more accurately determined than by standard truck or pile volume analysis programs. Further, the photographs are a permanent record of the mine history in terms of the volume analysis, exposed geology, and mine excavation stages.

Conventional Surveying Method

Conventional surveying equipment, unlike photogrammetric equipment, is readily available in the mine and its operation is very familiar to the mine surveyors. This aspect makes conventional survey methods very appealing for

data acquisition. Photogrammetric data acquisition would require contracting out surveyors and equipment, while conventional survey data acquisition could be accomplished by the mine surveyors and mine equipment. Depending on the present workload of the mine surveyors, this could be a much more attractive method.

Conventional survey methods would, like photogrammetric methods, require "observation stations" located in the pit or on the spoil side of the pit facing the exposed geology. These points would again require relative accuracy to at least (+/-) 1 cm or better to ensure that boundary points were also determined within this range. This could easily be accomplished using 3-dimensional survey measurements and reducing these measurements using a 3-D least squares adjustment program (3). The entire procedure including 3-D survey, adjustment, and data base formulation is estimated to require no more than 1 day. This represents a substantial improvement over the duration necessary for photogrammetric data acquisition, and is therefore considered initially as the better method.

Conventional survey observations could easily be repeated enabling more frequent updating of the coordinate data base. Conventional surveys are also less dependent on weather. However, obtaining a coordinate data base which defines accurately all the "anomalies" in the coal seams could be extremely difficult using conventional survey methods whereas photogrammetry enables easy digitizing of such features. Thus conventional survey methods could only feasibly be used if the exposed seams are very planer and of relatively homogeneous thickness. Again this method would yield a good volume analysis but no pictorial record of the exposed geology or mine excavation stages.

DATA BASE INTERPRETATION/MANAGEMENT

Once the coordinate data base has been created, a system must be designed which will interpret this data base in "real-time" mining operations. Eventually, a computer automated system must certainly be adopted which automatically raises or lowers the cutting head on the "Easi-Miner" from interpretation of the coordinate data base. The computer simply establishes the cutting head's position within the "DTM", determines the corresponding cutting depth desired, and relays the necessary cutting head adjustment. This would be a "real time" operation with continuous cutting head adjustment at prescribed intervals. If, for example, too much vibration is encountered, the operator or guidance system could raise the cutting head until such vibrations were reduced, and the system would simply record the new cutting elevation and corresponding position within the DTM. Alternatively, the velocity of the "Easi-Miner" could be reduced, limiting machine vibration and avoiding the formation of a step on the working bench. Obviously the accuracy of the system is a function of its ability to "remember" what has been excavated within the DTM block, and "interpret" what remains to be excavated to efficiently mine the block through a series of coal and waste excavating passes. Data base interpretation and management is basically a "software" problem, but may be considerably more difficult than initially expected due to the extremely large amount of data.

UPDATE OR ADJUSTMENT SYSTEM

In order for the system to accurately determine the cutting head's position (x,y,z) within the DTM for any given instant, a position "update" or "adjustment" system must also be incorporated. The most critical component of the position determination is obviously the elevation (z) component, and thus a very precise system must be incorporated to give instantaneous cutting head elevation within the DTM. An automatic rotating laser level may be utilized to accomplish this task (4).

The laser would be set up outside mine traffic a known elevation and at a location permitting unobstucted sighting to the "Easi-Miner". The laser detector would be mounted on the "Easi-Miner" enabling continuous elevation update which would be downloaded into the computer. The laser system can operate in two different "modes", one mode (Survey) would simply record the cutting head elevation as the "Easi-Miner" traversed the block, while the other mode (Layout) enables a fixed elevation to be maintained.

The "Survey" mode would be used when the possibility of encountering a different underlying material is negligible (for example while cutting the top layer of a coal seam whose thickness is greater than the maximum depth of cut). Thus the laser system would be used as an update system defining the elevation of the cutting head within the DTM. From these measurements the computer will be able to determine the depth remaining until a different underlying material will be encountered.

The "Layout" mode would be used when the cutting head is within range of excavating a different underlying material. Using a display system, the operator, monitoring the display lights, manually positions the cutting head to a depth corresponding to the desired elevation as defined by the coordinate data base. The display system may be an on-board indicator showing projected and actual cutting head elevation. Also, a system of "High", "Low", and "On Grade" lights could be used to assist the operator in maintaining the desired elevation, however as mentioned earlier, it would be much more efficient to program the computer to detect these conditions and eventually automate the entire procedure. Once the current seam has been efficiently mined with minimal contamination from underlying material, the system would then be switched back to "Survey" mode and mining continued until again the next coal boundary is within range of the cutting head. Automatic rotating laser levels have been used for construction applications for many years and their accuracy and reliability are well proven (5).

The (x,y) components of the position of the cutting head within the DTM must also be determined for any given instant. For simplicity, it is

suggested that the coordinate system be oriented with "x" along the direction of "Easi-Miner" travel and "y" perpendicular to the direction of travel. Thus, it is recommended that a "dead reckoning" system be incorporated on the "Easi-Miner" to determine the "x" component of its position within the DTM. Because the "Easi-Miner" excavates in a series of "passes" within the block, the "dead reckoning" system can easily be re-calibrated to define the known "x" coordinate corresponding to the end of each particular line. Further, the system would be very accurate for "x" component determination because of the relatively short distance the "Easi-Miner" would travel before re-calibration.

The "y" component of the position of the cutting head within the DTM is even easier to determine. Knowing the width of the cutting head (ie. the width of each cut), and assuming the "Easi-Miner" excavates parallel lines sequentially through the block, the system can determine the "y" component of the cutting head's position simply by knowing which line is presently being cut in reference to the side of the block. In order to maintain accurate "y" component determination throughout the entire block, the mine surveyors could plant lath at the ends of each line, and possibly along the path of the very first line in the block, from which the "Easi-Miner" operator could easily align the cutting head. The "y" component of the position of the cutting head is the least critical and thus this system is quite sufficient for its determination.

Eventually, "x","y" and possibly "z" coordinate determination could be accomplished using radio or satellite positioning technology (6).

CONCLUSIONS AND RECOMMENDATIONS

The development of a computerized guidance system for the "Easi-Miner" mining machine has been proposed. This system is seen as a means of improving the efficiency of the mining operation, specifically, by reducing the dependence on human judgement for detecting material changes, to ensure minimal contamination of coal from partings and interburden and improve coal recovery.

Improved coal recovery may be demonstrated in the following example:

> The coal strata at the Bienfait Mine in Saskatchewan where the "Easi-Miner" is being employed, consists of a block containing four coal seams separated by partings, approximately 6 m thick in total. The block is 150 m long. Coal seams and partings are of uniform thickness, having longitudinal dip of up to 1%, declining 1-2% in section. The coal sequence is covered by 20-30 m of overburden material, planned to be removed by dragline. The "Easi-Miner" is proposed to be used to remove coal and waste, having the following thickness (from top to bottom):

```
------------------------------
     coal - 35 cm
------------------------------
  parting - 45 cm
------------------------------
     coal - 240 cm
------------------------------
  parting - 20 cm
------------------------------
     coal - 68 cm
------------------------------
  parting - 110 cm
------------------------------
     coal - 73 cm
------------------------------
```

> In a four seam sequence, such as that found at the Bienfait mine, with an aggregate coal thickness of 4 m, accurate horizon control can minimize coal lost or ash included in ROM coal. There are eight coal/rock contacts in

the section to be excavated by the "Easi-Miner". With the computerized guidance system proposed in this report, it is believed that the "Easi-Miner" can be controlled to within (+/-) 1 cm of desired grade. If the geological structure can be defined to a similar level of accuracy, the benefit, in terms of increased clean coal recovery or reduced ash contamination as compared to manual machine control techniques, is very apparent.

Assuming approximately a 4 m wide cut during the "Easi-Miner" operation, coal quantity from the 150 m block, without cutting any waste material, is expected to be 2978 t using "visual" guidance system, compared to 3263 t recovered by using the proposed computerized guidance system. Theoretically, a production increase of up to 9.5% may be expected.

Photogrammetric and conventional surveying methods are outlined for digital terrain model (DTM) data acquisition. Both methods are seen to meet the desired accuracy requirement, however, each method must be considered in context of the specific needs and conditions of the particular mine. The requirements of data base interpretation and management have been presented and are recognized as a "software" problem involving book-keeping, data manipulation, and data storage. A system for elevation updates was also described using an automatic rotating laser level. This system has proven capabilities for elevation determination and provides excellent versatility to adapt to the specific problems encountered in developing this guidance system to the mining environment. Systems for (x,y) position updates were also described which are simple and inexpensive to implement and yield very acceptable accuracy for the instantaneous determination of these components of the cutting head's position within the DTM.

A block diagram (flow chart), illustrating the main procedures involved in creating and using the guidance system, is found in the appendix

(Page 14). Although the diagram is very general, it serves as a quick reference and brings together most of the ideas presented.

It is recommended that a detailed feasibility study be undertaken, using a simulated model, to outline costs and scheduling for the development and demonstration of the described system.

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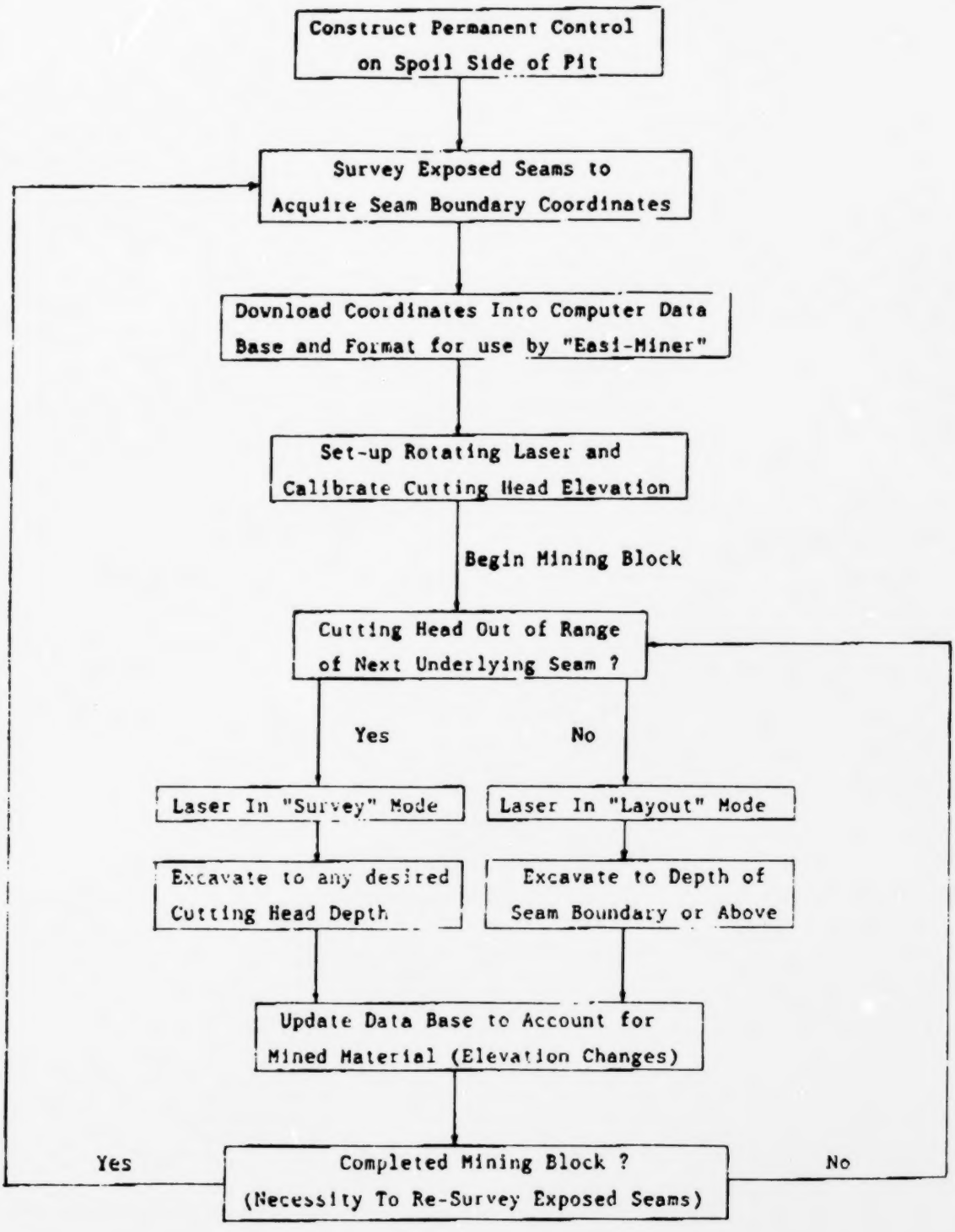
APPENDIX


Construct Permanent Control on Spoil Side of Pit
Survey Exposed Seams to Acquire Seam Boundary Coordinates
Download Coordinates Into Computer Data Base and Format for use by "Easi-Miner"
Set-up Rotating Laser and Calibrate Cutting Head Elevation
Begin Mining Block
Cutting Head Out of Range of Next Underlying Seam ?
Yes
No
Laser In "Survey" Mode
Laser In "Layout" Mode
Excavate to any desired Cutting Head Depth
Excavate to Depth of Seam Boundary or Above
Update Data Base to Account for Mined Material (Elevation Changes)
Completed Mining Block ? (Necessity To Re-Survey Exposed Seams)
Yes
No

Block Diagram illustrating main procedures for creating and using Computer Guidance System.